



**American Motors
Sales Corporation**



**Facts About . . .
METRIC MEASUREMENTS**

INTRODUCTION

One of the earliest attempts to establish an internationally accepted system of measurements occurred in 1791. At that time, the French Academy of Sciences met to discuss the proposition, resulting in the metric system.

Major changes in the system took place over the years. And in 1960, the General Conference of Weights and Measures refined the metric system into one that is being used, or adopted, by most of the major nations of the world. The United States is in the process of changing over to metrics.

American Motors Corporation believes its people should be aware of the move to metrics. This reference book — and the film that accompanies it — contain the facts you need to know about using metric measurements and tools.

View the film "Metric Measurements" with this book. And complete the various "Checkpoints" along the way. You'll see that metric measurements are easy to understand.

©Copyright 1979, American Motors Sales Corporation.
All Rights Reserved

CONTENTS:

Introduction	Inside Front Cover
Checkpoint #1	1
METRIC MEASUREMENTS	
Linear	2
Checkpoint #2	3
Mass	4
Volume	5
Torque	6
Pressure	7
Temperature	8
Checkpoint #3	9
METRIC TOOLS	
Metric Ruler	10
Metric Micrometer	11
Dial Indicator	12
Checkpoint #4	13
TABLE OF METRIC UNITS AND APPLICATIONS	14



Checkpoint

Instructions: Check your basic knowledge of metric measurements. Indicate the correct answer by circling the correct letter.

1. What is the metric unit for linear measurement?
(A) meter (C) newton-meter
(B) liter (D) kilopascal
2. Newton-meter is the metric unit for
(A) length (C) torque
(B) mass (D) pressure
3. The air pressure in a tire would be measured in
(A) kilograms (C) kilometers
(B) kilopascals (D) newtons
4. Which measurement is the largest?
(A) 100 mm (C) 0.50 m
(B) 90 cm (D) 0.01 km
5. A metric micrometer can be used to measure thickness in
(A) inches (C) centimeters
(B) millimeters (D) newtons

METRIC MEASUREMENTS

Linear

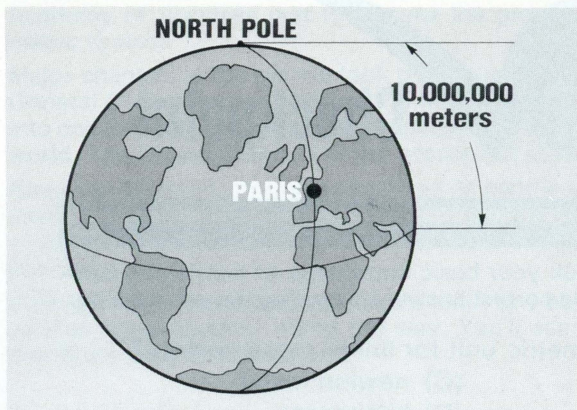


Figure 1. The meter was originally defined as one ten-millionth of the distance from the North Pole to the equator through Paris, France.

The base unit for length in the metric system is the *meter*. It's slightly longer than a yard — 39.37 inches, or about 10% longer. The symbol for the meter is a lower-case "m."

Derivations of the meter are formed in a scientific way, using the decimal system. Easy-to-remember submultiples and multiples of 10, 100 and 1000 can easily be formed by moving the decimal point one place to the right or left. And metric prefixes are used with the base unit to indicate these larger or smaller units. For instance, "kilo" means 1000, "deci" means one-tenth, "centi" means one-hundredth, and "milli" means one-thousandth.

For example, beginning with a base unit of one meter, moving the decimal point to the left gives us 0.1 of that unit or the submultiple *decimeter*. Similarly, 0.01m is one *centimeter*, and 0.001m is one *millimeter*. Conversely, moving the decimal point to the right expresses multiples of the base unit — the most common being the *kilometer*, or 1000 meters. A kilometer is equal to 0.6214 miles.

These are the symbols for the common multiples and submultiples of the meter:

kilometer — km • centimeter — cm • millimeter — mm

Kilometers are used for measuring long distances; meters are used for measuring such specs as turning circle radius; centimeters are used in the general dimensions of vehicles as well as glass and fabric areas; and millimeters are used for such measurements as spark plug threads and wrench sizes. In automotive service, you will normally make the most use of millimeters.

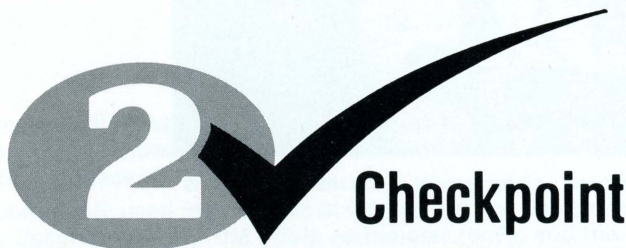
Conversion Factors

To convert inches (in) to millimeters (mm): multiply the number of inches by 25.4.

To convert millimeters (mm) to inches (in): multiply the number of millimeters by 0.04.

To convert miles (mi) to kilometers (km): multiply the number of miles by 1.609.

To convert kilometers (km) to miles (mi): multiply the number of kilometers by 0.6214.



Instructions: Each incomplete statement tests your knowledge of linear measurements. Fill in the correct answer.

1. The base unit for linear measurement in the metric system is the _____.
2. One one-thousandth (0.001) of a meter is a _____.
3. The prefix "kilo" means _____.
4. "cm" is the symbol for _____.
5. One centimeter is equal to ten (10) _____.
6. Change 850 mm to "cm": _____.
7. Change 35 centimeters to millimeters: _____.

METRIC MEASUREMENTS (Continued)

Mass (Weight)

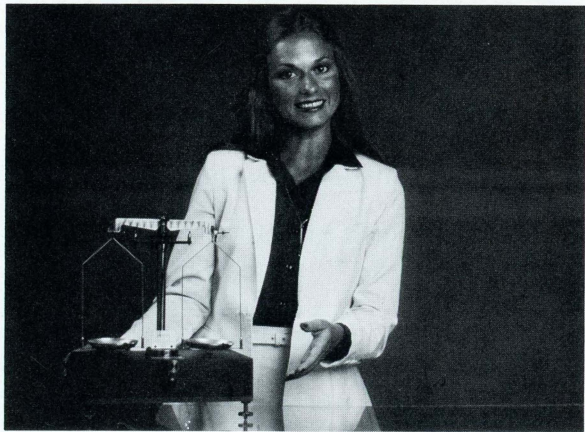


Figure 2. The base unit for weight in the metric system is the kilogram.

Mass is defined as the quantity of matter in an object. The base unit of mass in the metric system is the *kilogram*, and its symbol is "kg." A kilogram is equal to 2.2046 pounds.

The kilogram is the only meter base unit that has a prefix as a part of its name. The term "kilo," of course, means one thousand. So, a kilogram is a thousand grams. In most everyday situations, the kilogram is more commonly used than a gram, because the gram is such a small unit.

Conversion Factors

To convert ounces (oz) to grams (g): multiply the number of ounces by 28.

To convert grams (g) to ounces (oz): multiply the number of grams by 0.035.

To convert pounds (lb) to kilograms (kg): multiply the number of pounds by 0.45.

To convert kilograms (kg) to pounds (lb): multiply the number of kilograms by 2.2.

Volume

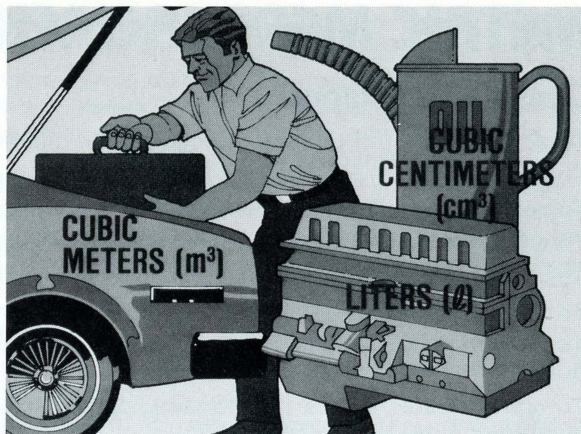


Figure 3. Various units are used to express volume in metric terms . . . cubic meters, liters, cubic centimeters.

Volume is defined as space occupied in three dimensions, as measured by cubic units. It is used to measure the amount of space occupied by solids, liquids, and gases.

The commonly used metric units of volume are: the *cubic meter* (m^3); the *cubic decimeter* (dm^3); the *cubic centimeter* (cm^3); and the *cubic millimeter* (mm^3).

The cubic decimeter, called a *liter*, is commonly used for fluid volume, especially in packaging. The recognized symbol for the liter is a lower-case "l."

A liter is about five-percent larger than a United States quart. To be precise, one liter equals 1.0567 U.S. quarts.

METRIC MEASUREMENTS (Continued)

Conversion Factors

To convert pints (pt) to liters (l): multiply the number of pints by 0.47.

To convert liters (l) to pints (pt): multiply the number of liters by 2.1.

To convert quarts (qt) to liters (l): multiply the number of quarts by 0.95.

To convert liters (l) to quarts (qt): multiply the number of liters by 1.06.

To convert gallons (gal) to liters (l): multiply the number of gallons by 3.8.

To convert liters (l) to gallons (gal): multiply the number of liters by 0.26.

To convert cubic centimeters (cm^3) to cubic inches (in^3): multiply the number of cubic centimeters by 0.061.

To convert cubic inches (in^3) to cubic centimeters (cm^3): multiply the number of cubic inches by 16.39.

To convert liters (l) to cubic inches (in^3): multiply the number of liters by 61.02.

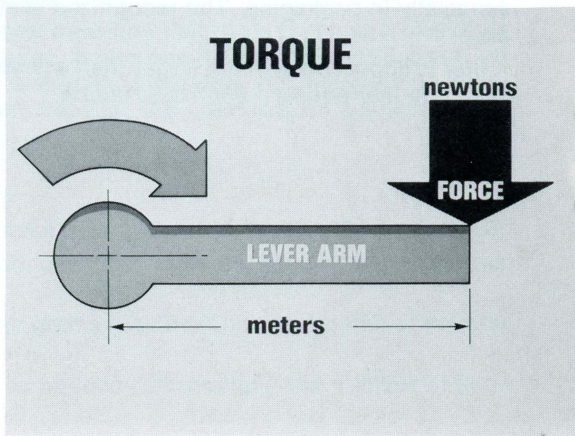
To convert cubic inches (in^3) to liters (l): multiply the number of cubic inches by 0.01639.

To convert cubic centimeters (cm^3) to liters (l): divide the number of cubic centimeters by 1000 (simply move the decimal point three figures to the left).

To convert liters (l) to cubic centimeters (cm^3): simply move the decimal point three figures to the right.

Torque

Figure 4. The unit for torque in the metric system is the Newton-meter.



Torque is defined as applying a certain force to a lever arm to rotate an object about a point.

In the metric system, force is expressed in *newtons*, and the length of the lever arm is expressed in *meters*. Therefore, torque is force in newtons, times length (of the lever arm) in meters. The unit of torque is the *Newton-meter*. The metric symbol for the Newton-meter is capital "N," small "m." Metric torque wrenches are calibrated in Newton-meters. Torque is read on the dials of such wrenches. Some older torque wrenches are calibrated in foot-pounds, with kilogram-meters as the metric equivalent. Kilogram-meters was an earlier metric measurement for torque.

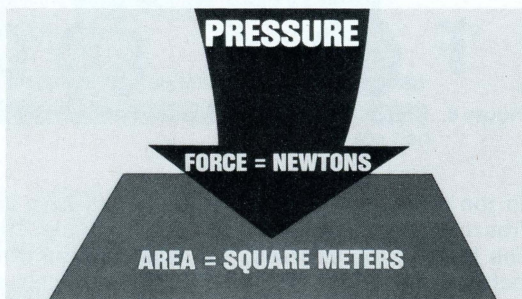
Conversion Factors

To convert foot-pounds (ft-lb) to Newton-meters (N·m): multiply the number of foot-pounds by 1.3.

To convert inch-pounds (in-lb) to Newton-meters (N·m): multiply the number of in-lb by 0.11.

Pressure

Figure 5. Pressure is the force in Newtons per square meter.



Pressure is force per unit area. Pressure is determined by the force being applied and the area over which the force is distributed. In metric terms, force is expressed in Newtons (N) and area is expressed in square meters (m^2). So, pressure is actually the force in newtons per square meter of area.

The metric unit of pressure is the *pascal*. The symbol for the pascal is "Pa." One pascal of pressure equals one newton of force per one square meter of area.

However, one pascal is a very small amount of pressure. So, the *kilopascal* is the recommended unit for fluid pressure for all fields of use. The symbol for the kilopascal is "kPa." One kilopascal equals 1000 pascals.

Conversion Factors

To convert pounds (lb) to Newtons (N): multiply the number of pounds by 4.45.

METRIC MEASUREMENTS (Continued)

Temperature

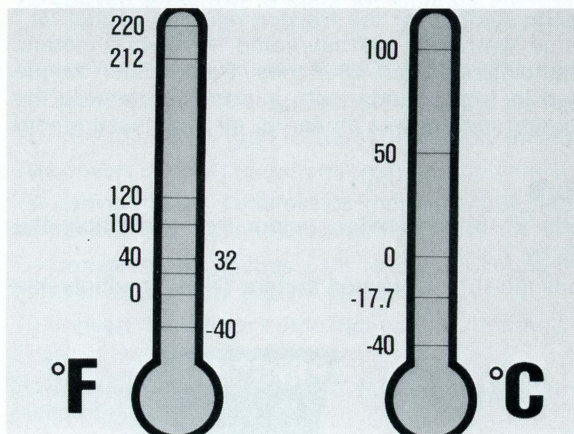


Figure 6. Comparison of the Celsius scale and the Fahrenheit scale.

In the metric system, a temperature of zero degrees is assigned to the freezing point of water on the Celsius scale. The boiling point of water at sea level is 100 degrees. The scale is then divided into 100 equal parts between these two points. The Celsius scale *extends above and below freezing and boiling*. The symbol for degree Celsius is “°C.”

NOTE: The Celsius scale is exactly the same as the Centigrade scale that has been in use for some time. It has been renamed to avoid confusion in a few countries where a similarly named unit is used to express a different type of measurement.

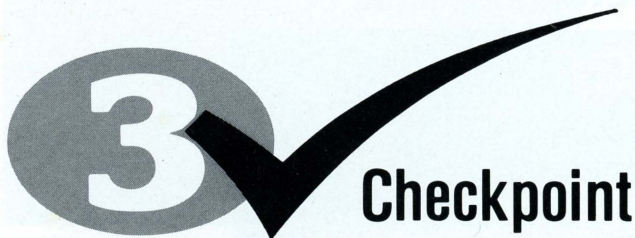
Obviously, the Fahrenheit scale that the United States has been accustomed to differs from the Celsius scale. Degrees “C” are larger than degrees “F.” Therefore, *smaller* numbers will be used in your service temperature specifications (See Figure 6).

A temperature of one degree Celsius is approximately the equivalent of 1.8 degrees Fahrenheit, which might indicate that the Celsius scale is less accurate. This isn't the case, however, since tenths of a degree Celsius can be used when this much accuracy is required.

Conversion Factors

To convert Fahrenheit ($^{\circ}\text{F}$) to Celsius ($^{\circ}\text{C}$): take the number of degrees Fahrenheit and subtract 32; multiply the result by 5; and divide the result by 9.

To convert Celsius ($^{\circ}\text{C}$) to Fahrenheit ($^{\circ}\text{F}$): take the number of degrees Celsius and multiply by 9; divide the result by 5; and add 32 to the total.



Instructions: The following incomplete statements test your knowledge of the metric units used for length, weight, torque, pressure, volume and temperature. Fill in the correct answer.

1. Spark plug thread sizes are given in _____.
2. The base unit for weight in the metric system is the _____.
3. A typical torque spec for spark plugs is 30 _____.
4. Kilopascals is the unit you will work with for _____.
5. One liter is about _____ percent larger than a quart.
6. Degrees _____ are smaller than degrees _____.

METRIC TOOLS

There are many specialized types of metric tools and instruments available for measuring a variety of objects. However, the specific tools covered in this booklet are the metric ruler (15cm scale), the metric micrometer and the metric dial indicator. All of these instruments measure in units of length; i.e., linear measurements.

Metric Ruler

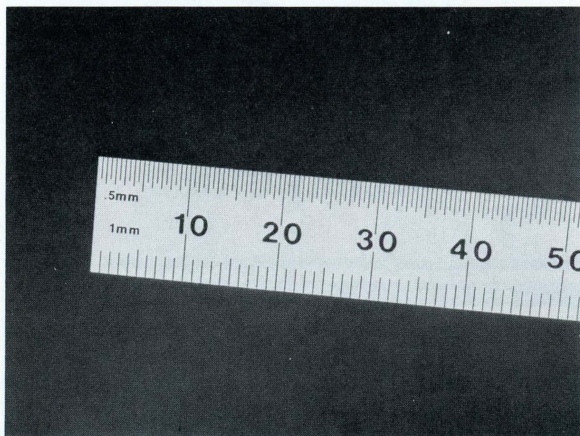


Figure 7. The metric ruler is divided into centimeters and millimeters.

The *metric ruler* is a simple measuring device, used to make measurements on flat surfaces. A 150mm ruler, also known as a 15cm ruler, is divided into 15 large segments, each one centimeter long. Each centimeter is divided into 10 equal parts, called millimeters. In some instances, half-millimeter marks also appear on the scale, so measurements to 0.5mm can be made accurately. To use the scale, simply lay it along the item to be measured and read the scale.

Metric Micrometer

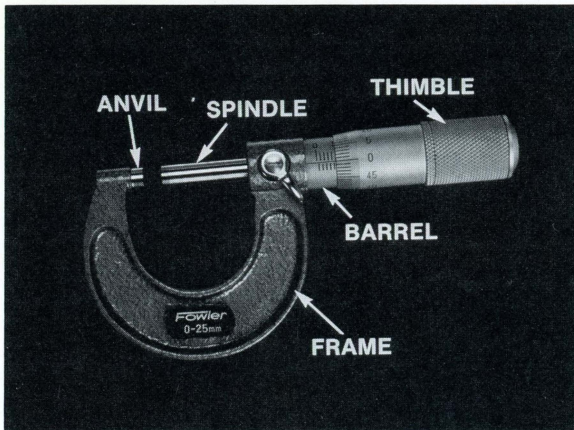


Figure 8. A metric micrometer.

The *metric micrometer* is designed for jobs that require a more accurate measuring device than a ruler. It can measure to one one-hundredth of a millimeter.

The micrometer has five basic parts — the frame, anvil, spindle, barrel and thimble. When you turn the thimble, it moves along the barrel and the spindle moves toward the anvil.

With most metric micrometers, one full turn moves the thimble one-half (0.5) millimeter. So, it takes two full turns of the thimble to move it one full millimeter.

The micrometer has two scales. The first scale is called the main scale. The second scale is movable, and is called the thimble scale.

The main scale gives readings accurate to one-half millimeter. The marks above the line, also known as the "datum" line, indicate full millimeters. The marks below indicate half millimeters.

The thimble scale gives readings accurate to one one-hundredth of a millimeter. There are 50 lines or divisions on the thimble scale. Each represents one one-hundredth millimeter, so all 50 add up to one-half millimeter.

To take a reading, first read the main scale to the nearest one-half millimeter. Second, read the thimble scale. Third, add the two values for the total reading.

METRIC TOOLS (Continued)

Metric micrometers are used in the same manner as are inch micrometers. The only difference lies in the fact that we're reading in metric units — millimeters and hundredths of millimeters. Micrometers are available in various sizes:

0mm to 25mm
25mm to 50mm
50mm to 75mm
75mm to 100mm and larger

Dial Indicator

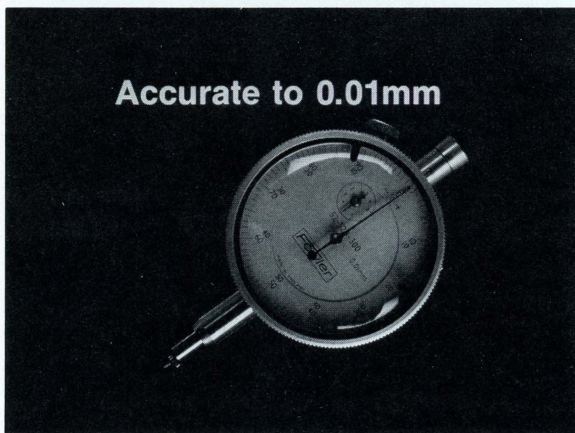


Figure 9. A dial indicator is accurate to 0.01mm.

Another tool used for linear measurement is the *dial indicator* — excellent for measuring crankshaft play, cylinder wear and other out-of-round conditions.

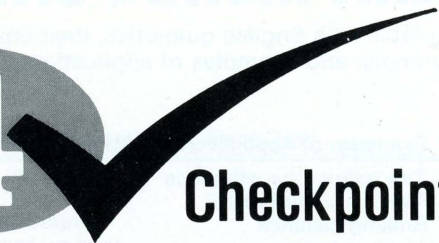
The dial indicator, like the micrometer, is accurate to one one-hundredth of a millimeter. It has two needles, one small and one large.

The small needle counts full millimeters. Depending on the brand of dial indicator, this needle will measure up to ten or twenty millimeters.

The large needle measures hundredths of a millimeter. There are 100 lines or divisions on this scale. So, one complete revolution of the indicator on this scale would be one millimeter.

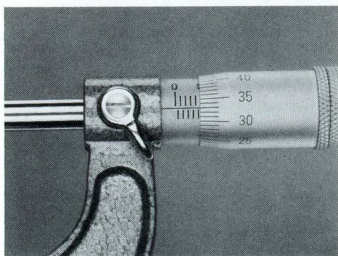
To take a reading, simply read the small needle scale, the large needle scale, and then add the two values for a total.

4

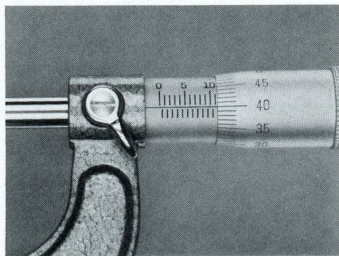


Checkpoint

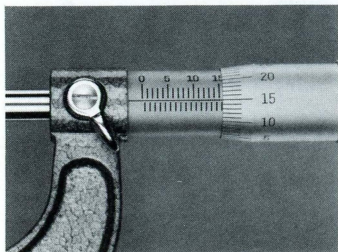
Instructions: Test your knowledge of reading a micrometer and dial indicator. Fill in the correct readings next to each picture.



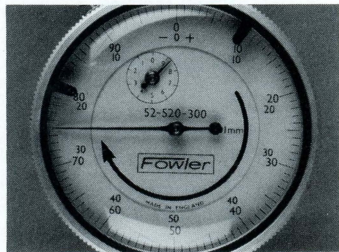
1. The first micrometer reading is _____.



2. The second micrometer reading is _____.



3. The third micrometer reading is _____.



4. This dial indicator reading is _____.

MODERN METRIC UNITS

The following table lists English quantities, their equivalent metric units and metric symbols, and examples of applications.

Quantity	Examples of Applications	Metric Unit	Symbol
Length	Tire rolling circumference	meter	m
	Turning circle/radius		
	Braking distance		
Area	Greater than 999 meter	kilometer	km
	Dimensions (general)	millimeter	mm
	Glass & fabrics	square centimeter	cm ²
Volume	Brake & clutch linings		
	Radiator area		
	Small areas	square millimeter	mm ²
Volume Flow	Car luggage capacity	cubic meter	m ³
	Engine capacity	liter	l
	Vehicle fluid capacities	cubic centimeter	cm ³
Velocity	Gas & liquid	liter per second	l/s
Frequency	General use	meter per second	m/s
	Road speed	kilometer per hour	km/h
	Electronics	hertz	Hz
Mass		kilohertz	kHz
		megahertz	mHz
	Vehicle weight	megagram	t
Density	Legal load rating		
	General use	kilogram	kg
	Small masses	gram	g
Force		milligram	mg
	General use	kilogram per cubic meter	kg/m ³
		gram per cubic centimeter	g/cm ³
Moment of Force (Torque)		kilogram per liter	kg/l
	Pedal effort	Newton	N
	Clutch spring force		
	Handbrake lever effort		
	Torque	Newton-meter	N·m

Quantity	Examples of Applications	Metric Unit	Symbol
Power, Heat Flow Rate	General use	watt	W
	Bulbs Alternator output Engine performance Starter performance	kilowatt	kW
Celsius Temperature	General use	degree Celsius	°C
Fuel Consumption	Vehicle performance	liter per 100 kilometer	l/100km
Oil Consumption	Vehicle performance	liter per 1000 kilometer	l/1000km
Pressure	Tire	kilopascal	kPa
	Coolant		
	Lubricating oil		
	Fuel pump delivery		
	Engine compression		
	Manifold		
	Brake line (hydraulic)		
	Car heating and ventilation		
	Barometric pressure		

NOTES



**American Motors
Sales Corporation**

FORM NO. 7187791100RB